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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

FOREST INSECT INVESTIGATIONS

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SUMMARY OF INFORMATION ON IPS CONFUSUS

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341 Giannini Hall, U. C.
Berkeley 4, California
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U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE
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SUMMARY OF INFORMATION ON *IPS CONFUSUS*

from

Notes and Report Files of the Forest Insect Laboratory
Berkeley, California

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341 Giannini Hall, U. C.
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SUMMARY OF INFORMATION ON *IPS CONFUSUS*

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Notes and Report Files of the Forest Insect Laboratory
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I. MATERIAL AVAILABLE

Although very few reports dealing with the biology of the California Five-spined Engraver beetle, *Ips confusus* Lec., are on record, the Hopkins Note Files contain many entries pertaining to this insect. Going back to 1910 we find a list of 158 separate note entries in which observers have considered this beetle to be of sufficient importance to put its activities on record. For the most of these records, identification of the beetle had been made by field entomologists who were qualified to distinguish the species and there can be little question of the determinations. In a number of cases, specimens were later referred to specialists of the National Museum for final determinations.

In addition to the Hopkins Notes there are three reports dealing with the biology of *Ips confusus* and a number of survey reports which contain references to the behavior of infestations in certain areas.

II. DISTRIBUTION

The geographical distribution of the Hopkins note entries includes localities throughout the westside pine type from the Rogue River drainage in Southern Oregon to the Lagunas Mountains in Southern California. The frequency with which the beetle has been recorded in the Pacific Coast type is best shown in the following summary by sub-regions:

Sub-region	Number of Note Entries
Southern Oregon, mainly Rogue River drainage	17
Northern California, westside types in Moffat Creek, Lower Klamath, Trinity, Upper Sacramento, and lower Pitt Rivers	10
West slope Sierras, Feather River to Mokelumne River	61
West slope Sierras, Mokelumne River to Kern River	35
Coast Range, Cobb Mountain area	2
Coast Range, Mt. Hamilton, Santa Cruz, Carmel River and Figueroa Mountain	7
Southern California - Tejon Pass	1
San Bernardino Mountains	8
Julian, Lagunas (Cleveland N. F.)	5
Total	157

There is also one record from Prescott, Arizona, which records *Ips confusus* emerging from *D. barberi* infested bark shipped to the California field laboratory for rearing.

The distribution of *I. confusus* as represented by Hopkins notes is shown on an outline map of California, Figure 2.

It is worthy of note that there are no records of Ips confusus from east of the Cascade Mountains in Southern Oregon and Northern California. Also it has not been recorded east of the Sierra Nevadas except where pinon, Pinus monophylla, occurs. The most northern record of the beetle east of the Sierras is in pinon near Mammoth, California, and from here down to the Mexican border there are sufficient records to indicate that it occurs regularly in the pinon types.

III. RECORDED HOSTS

The Hopkins records show 10 species of pines as hosts. Two records give other conifers as hosts, but it seems fairly obvious that these were accidental. In 1924, Dr. E. P. Meinecke sent in material from a top-killed white fir attacked by Scolytus ventralis which included one specimen identified by Dr. W. M. Blackman as Ips confusus. However, there were no data to indicate that Ips had actually attacked this tree. In 1914, Dr. H. E. Burke collected an adult from the bark of incense cedar, but here again there was no evidence of actual attack.

1. Pinus attenuata, Knobcone pine.

Ips confusus was first recorded from this host in 1940 by K. A. Salman near Mt. Shasta where it was killing numerous groups of trees. Again in 1941, Patterson and Yuill collected material from the same general vicinity, noting "about 50 trees killed in group in 1940 and earlier" at Dead Horse Summit, Siskiyou County, California.

2. Pinus balfouriana, Foxtail pine.

One specimen was collected in 1910 by J. M. Miller from a dying foxtail pine near Brewer Creek, head of South Fork of King's River, at an elevation of 10,000 feet.

3. Pinus coulteri, Coulter pine.

There are 12 note entries from Coulter pine which are spread throughout the range of this host tree from Mt. Hamilton to the Lagunas Mountains. In this host tree the beetle is distinctly a top-killer of the larger trees, and is capable of developing virulent epidemics when it attacks trees in large groups. Follow-up of western pine beetle infestation in the green bases of trees top-killed by Ips confusus is a very common association during epidemic periods. Pole-sized trees are occasionally entirely killed by Ips.

4. Pinus jeffreyi, Jeffrey pine.

There are but two records from Jeffrey pine, both in Southern California. In each case the notes indicate that I. confusus was attracted to trees which had been injured or dying. There are no records from Jeffrey pine east of the Cascades or Sierras.

5. Pinus lambertiana, sugar pine.

Although I. confusus is known to be quite common in the top-killing of sugar pine and in attacks associated with the mountain pine beetle, there are but 6 note records from this host. At Ashland, Oregon, in 1916 Keen recorded I. confusus as responsible for killing one sugar pine and in another tree it was found to be associated with D. monticolae; at Pinecrest, California, it was recorded in sugar pine slash; and in the Yosemite National Park, Struble records it as attracted to a trap tree. Other notes in the central and southern Sierra record the beetle in trees killed by D. monticolae. In a report dealing with the mountain pine beetle in sugar pine, Struble (5) stated that:

> "When aggressive attacks of Ips occur, sugar pines are weakened and more susceptible to D. monticolae invasions, resulting in more rapid death. Arrested attacks of Ips resulting in red or snag-topped sugar pines are infrequent.
>
> "Infestation records of 112 sugar pines taken at different periods from 1932 to 1940 showed that 43 percent of them contained Ips top-kill infestations, 4 percent contained flatheads in the top, and 6 percent contained mixed infestations of D. monticolae and flatheads; the remaining 47 percent contained pure mountain pine beetle infestations."

It is accepted that these references to Ips attacks in sugar pine refer to Ips confusus which is the species most commonly identified by Struble in the Sierra areas where his studies were made.

6. Pinus monticola, western white pine.

There are but two records from this host. In 1910 Miller collected the beetle from an infested tree at the 10,000 foot elevation in the King's River country; and in 1929 he collected it at Snow Flat, Yosemite National Park, where he observed that "Ips confusus had attacked cambium areas which had not been mined by D. monticolae."

7. Pinus monophylla, pinon pine.

In 1928 Keen found an Ips confusus infestation near Big Bear Lake in the San Bernardino National Forest which was characterized by "large groups of pinon pine dying from bark beetle attack, in some places all trees killed on an acre or two in extent." While there are no further note entries from this locality, survey reports from 1930 to 1940 indicate that the condition reported by Keen continued in the pinon stands. The groups reported were quite localized and persisted from year to year with trees continuing to die around the perimeter of the original group. Investigations by Wagner and DeLeon in 1938 found a root fungus (Fomes) connected with the dying of these groups and indications were that the Ips beetles were largely secondary. There are but two other note records in this host from localities at Gorman, and Mammoth, California.

8. Pinus ponderosa, ponderosa pine.

The Hopkins note files contain 114 entries from this host; some 62 of these records were made by Burke and Herbert in the vicinity of Placerville, California, and the remainder were made by a number of observers from localities throughout the westside pine type from southern Oregon to the San Bernardino Mountains.

This large accumulation of notes shows that I. confusus quite commonly kills pole-size trees up to 20 inches D.B.H. in groups and top-kills the larger trees. While it is nearly always attracted to slash where it breeds prolifically, it has the ability to attack healthy vigorous trees. The history of past infestations have been characterized by sporadic but virulent epidemics when it attacks large groups of trees. D. brevicomis usually follows up these epidemic outbreaks and attacks the green bases of top-killed trees. In the westside pine type, short-lived Ips outbreaks have usually been the fore-runner of western pine beetle epidemics.

9. Pinus radiata, Monterey pine.

There are 8 records of Ips confusus in Monterey pine, all in the San Francisco Bay region. The first record was by Hartman in 1921 at Oakland. From 1926 - 1932 other records were secured on this host, usually in association with D. valens. Burke records group killing in Monterey pine plantations at Ormondale Ranch, San Mateo County, in 1932.

10. Pinus sabiniana, Digger pine.

In 1915 Herbert made 2 note entries of I. confusus collected from digger pines near Placerville. One was from a windfall and the other was in a tree felled for a trap. There are no records of primary attack by this beetle on digger pine.

IV. SEASONAL HISTORY DATA

The Hopkins notes contain many records of the brood stages of I. confusus found in infested trees at different periods of the year, but most of these do not lend themselves to interpretation of the seasonal generations. Many of the notes were taken during the winter season and these all agree fairly well in indicating that the beetle overwinters mainly in the young adult stage with some prepupal larvae and pupae. Some of the notes made by Herbert at Placerville give some data on development of the first seasonal generation. In addition to the notes, there are 3 reports giving data on seasonal history. These seasonal history data can best be reviewed by the localities where the records were obtained.

1. Southern Oregon (Rogue River Area)

Keen (1) summarized the Ashland records obtained during the seasons of 1915 and 1916 in a special report. He maintained brood records from a series of 18 trees, most of which were windfalls including ponderosa and sugar pines.

All of the records of completed brood development were for the first seasonal generation; and the only records from subsequent generations were notes secured from overwintering top-kills at the time when emergence was occurring in the spring. From his available material, Keen recognized two seasonal generations:

> "The attack of the first generation commences in the latter part of March and during April. The beetles develop and emerge during July and August. The brood period, as shown by the record trees, from first attack to first emergence averages 86 days.
>
> "From the data so far collected, it would seem that the generations of Ips confusus are much less complicated than those of D. brevicomis. The first seasonal generation develops in fallen timber from April to August, and the second generation then attacks the tops of thrifty and mature trees.
>
> "We have no record trees of the second generation, but from the examination of the top-killed trees in cruising it appears that there is a heavy emergence from these trees in March and April. No broods have been found overwintering in fallen timber, though this may be only a coincidence."

In 1922, Patterson (Hopk. 16242b) recorded I. confusus which had been attracted to a trap tree in the Soda Creek area near Ashland, Oregon. This record was obtained in connection with an experiment to test flight distances for D. brevicomis. A normal healthy tree was felled August 19 at an isolated point in the open valley, the location was a little over 2 miles distant from the nearest timbered area which contained infested trees. On September 15, the trap was found to be attacked by Ips confusus in association with D. brevicomis and D. valens. This seems to be the only record of the distance which Ips has been known to fly to attack traps.

2. West slope of Sierras, vicinity of Placerville, California.

At this locality, Burke and Herbert made a number of records during the spring of 1916 from infested trees, all ponderosa pines, near Placerville. The notes from 9 trees made February 16 and 17 apparently apply to overwintering broods; one tree (Hopk. 14417b) contained new adults and some emergence, while 8 trees (Hopk. 14418a - 14421a) contained larvae, prepupal larvae and new adults.

Seven records (Hopk. 14436a - 14447a) extending over a period from March 24 to April 16 record parent adults, eggs and young larvae; indicating that these were newly attacked trees of the first seasonal generation. Records show that a number of trees were attacked in March and emergence may even have occurred in February.

Some records on development of the first seasonal generation were obtained by Herbert (Hopk. 13590a - 13596a) from 5 trap trees which were felled in early November 1915. Herbert found all of these traps attacked by

April 4, 1916, when they contained parent adult and eggs, indicating that the attack had occurred in late March. In the traps the broods developed rapidly during May and by June 6 the broods were nearly all in the new adult stage.

Herbert (2) prepared a report summarizing the information collected at Placerville which goes into considerable detail in describing the habits of attack, construction of egg galleries, oviposition, and larval development. Following are some of the more significant points:

"The males attack the tree first.

"All my observations so far seem to indicate that it is only the winter brood which attacks standing timber; this seems to have been the case for the last 3 years in the vicinity of Placerville.

"There seems to be no true period of hibernation in the vicinity of Placerville; that is, development and activity do not cease but are only retarded. Attack and egg laying probably do not occur, however, in December, January and February.

"From the data I have collected, I would say that there are at least 3 full generations with a strong fourth and even a partial fifth generation. Table II showing event and duration periods gives an average of 77 days from first attack to first emergence. This is obtained by adding the average of all first event periods together. With the allowance for 10 days or so for flight and a considerably longer time for the development of the winter brood, this would indicate 4 full generations per year."

Herbert was not able to maintain brood records through August, September and October so that the periods during which the later seasonal generations occur are not indicated. His records do, however, show a first seasonal generation extending from the latter part of March to the first part of June; and a second seasonal generation from the first part of June to the latter part of July.

3. West slope of Sierras, vicinity of Northfork, California.

A study of the seasonal history of I. confusus was made in this area in 1932 by Furniss (3). A heavy epidemic of Ips confusus which had developed during 1930 and 1931 had emphasized the need for more information on the biology of this insect, and the study was undertaken to determine the number of seasonal generations and to secure other data on the behavior of this infestation. Most of the records were obtained in the vicinity of Bass Lake at elevations around 3,000 feet.

Furniss started his records with the overwintering generation of 1931 which was found entirely in top-killed trees. He found by climbing a number of trees that very little brood had been produced. "The adults seemed to have attacked and extended irregularly shaped galleries without attempting to lay eggs in any considerable numbers."

Seasonal history records for 1932 were obtained both from caged logs and from trap trees. The study was not started until after May 1 so earlier seasonal developments are lacking. The first attacks by emerged adults from overwintering broods occurred soon after May 1. Furniss roughly recognized 3 seasonal generations including the events from first attack to first emergence:

(1) from the early part of May to the middle of June.
(2) from the middle of June to the last part of July.
(3) from the first of August to the last part of September.

The brood periods recorded by Furniss are shorter than those found at Ashland. In 2 trap trees the mid-summer (June, July) period from attack to emergence was completed in about 35 days. All were completed in less than 60 days, the general average being close to 45 days during the summer.

No records were secured by Furniss after September 25 because of other assignments, so the question of a partial fourth or overwintering generation starting in October was left undecided. The sudden decline of the infestation in 1932 was a factor which left the results of the study in an unsettled state, since records from top-killed standing green trees were not available during the season. Furniss noted that:

> "During May, June and July Ips would fill in trap trees almost as soon as they were felled. After the middle of July, traps either did not fill in at all or were but lightly infested. This occurred on the same area where hundreds of trees had been attacked the year before, so a very decided reduction in numbers must have taken place."

4. Southern Sierras, Kaweah Area

In 1918 Miller (4) and Wagner followed the development of broods in trap trees consisting of two ponderosa and one sugar pine at elevations of 5000 to 5500 feet. The trees were felled during the latter part of May. According to the report "the broods developed fairly uniformly in all three trees. Attacks started about June 10 and emergence was nearly completed by July 25, a period of 46 days. No attacks were found which would provide suitable records for the second seasonal generation."

There is some question whether these trap tree records represent the first or second seasonal generation, but the high elevations where they were located supports the assumption that these were first generation broods. However, the topography of the Kaweah area is so precipitous that the trees could very well have been attacked by adults of the first generation which emerged from lower elevation trees and were attracted to these traps.

5. Southern California.

The few notes that are available indicate that in this sub-region the broods overwinter as advanced larvae, pupae and new adults; and emerge early in the spring, depending upon elevation and seasonal conditions. On the Figueroa area of the Santa Barbara National Forest in 1922 Miller (Hopk. 16653b) found

new adults on June 16 in a trap tree which had been felled the preceding winter, indicating that development of the first seasonal generation had been completed by that date. Another note in 1923 (Hopk. 16816b) indicates similar early season development.

6. San Francisco Bay Region.

Records by Burke mostly from Monterey pine refer to broods of larvae, pupae and new adults during the period from October to March, indicating that this is the overwintering condition. One record (Hopk. 16615d) shows parent adults and eggs on May 4. However, it is doubtful that the seasonal generations in this climatic zone can be compared to those in the mountain areas where the seasons are clear cut.

7. Summary of Seasonal Generations.

Broods of I. confusus overwinter in poles and the tops of standing infested trees mainly as new adults with some advanced larvae and pupae.

Emergence of the overwintering generation begins early in March at the lower elevations (Placerville records) and continues through April and May (Ashland and Northfork records).

Attacks of the first seasonal generation begin about March 15 (Placerville), continue during April (Ashland), the early part of May (Bass Lake), and may even occur as late as early June at the higher elevations (Kaweah area). These attacks are most common in windfalls and slash material when this is available.

Development of the first seasonal generation is completed in 45 days (Bass Lake and Kaweah) to 86 days (Ashland). The length of this period is undoubtedly influenced by elevation and seasonal temperatures.

Emergence of the first seasonal generation begins about the middle or last of June (Placerville and Bass Lake) and may occur as late as the latter part of July or early August (Ashland).

A second seasonal generation occurs in traps at lower elevations from the middle of June to the latter part of July (Bass Lake). This generation may complete development from attack to emergence in 35 days.

A third seasonal generation in the lower pine belt occurs in traps from the first part of August to the last of September and emerges before fall (Bass Lake). Under normal conditions it can be expected that this generation attacks mainly in standing green trees, but brood records have been secured only from trap material.

A partial fourth generation can be expected which attacks in late September and October and establishes the overwintering broods in the lower pine belt, although this has not been shown by the available records.

A chart of brood development as interpreted by seasonal generations from the records of the Ashland, Placerville, Northfork and Kaweah areas is shown in Figure 1.

V. BEHAVIOR OF IPS CONFUSUS INFESTATIONS

The available information on behavior indicates that under endemic conditions, Ips confusus infestations maintain themselves in recently felled down logs, tops and limbs; but they may also suddenly attack standing green trees on restricted local areas without causing widespread damage. These local outbreaks in standing trees do not last long and usually a local cause can be found, such as windfalls, slash from right-of-way clearings, or other temporary conditions that create a favorable but limited breeding place for Ips populations. A typical case of a local outbreak which is recorded in Hopkins notes 16833a and 16871a occurred near Nevada City in 1925. In second growth pine stands which were being selectively cut for mining timbers, groups of infested poles and top-killed trees suddenly appeared near the slash but this condition subsided during the following season. These local flare-ups seem to be a condition that may appear at any time without resulting in widespread damage.

On the other hand, Ips outbreaks have occurred in the past which included large areas and caused an immense amount of damage. These extensive outbreaks have been truly epidemic in character, although they were short-lived. Their causes have not always been obvious. The more serious of these epidemics have been in association with or followed by D. brevicomis which bred up in the top-killed trees and carried on the momentum of the epidemic for several years after Ips subsided. The character and behavior of these epidemics can best be gained by reviewing records of the more important outbreaks where Ips confusus was recognized as the species first involved in the increasing infestations.

1. Rogue River Areas, 1915-1916

This epidemic was characterized by the sudden appearance of groups of infested trees in the lower ponderosa pine type of the Rogue and Applegate watersheds in the late summer and fall of 1915. In 1916 the Ips confusus infestation declined rapidly, but D. brevicomis which also made a sharp increase in 1915 maintained a high level in 1916 and declined in 1917.

Keen (6) made an analysis of the I. confusus infestation on the Lambs Mine unit, an area of 3,200 acres near Ashland which was intensively cruised throughout the seasons of 1915 and 1916. In describing developments on this area, Keen (1) gave the following history.

> "The infestation on the Lambs Mine unit appears to have bred extensively in some tops and limbs on Section 22 left by wood cutters and the timber which was felled by a windstorm early in 1915. The beetles multiplying in this way appear to have attacked the tops of larger trees, so that in the fall of 1915 and the spring of 1916 we had a large number of these trees which have been called 'top-killed.' The increase in the infestation is as follows:

	Increase	Decrease
1915, first generation	74 %	
1915, second generation	79.4%	
1916, first generation		43.3%

"The decrease in 1916 is probably due to lack of wind-blown trees or other suitable material.

"The 1915 second generation developed almost altogether in standing trees, either small trees or in the tops of more mature trees. There were 54 small trees and 192 larger 'top-killed' trees representing this generation.

"Of the top-killed trees, 30 were climbed and examined and were all found to be infested with Ips confusus; 66 of the 'top-killed' trees were later attacked by one or more species of insects and entirely killed."

2. Sierra National Forest, 1912-1913

That there was a fairly general outbreak in the ponderosa pine type on the Sierra during this period is fairly well established by the reports of the Contour Insect Control Project which covered the lower ponderosa pine type from Cascadel to Jerseydale. E. G. Dudley (7) stated in his report:

"While this beetle (Tomicus confusus) prefers second growth pole stands and works from the top down, it is quite often found working in connection with Dendroctonus brevicomis. The second growth stand around Crane Valley (Bass Lake) and the north slope of Goat Mountain was badly infested by this species. The center of infestation appeared to be around Crane Valley Lake and had evidently been started by the flooding of pole stands at the time of the completion of the dam."

In the fall of 1913 Ralph Hopping (8) found additional infestations in the Jerseydale district. On the cutting areas of the Yosemite Lumber Company he found that:

"Tops and limbs had bred enormous quantities of Ips confusus and Ips oregoni, most of which had already emerged. These are the species which kill so many tops of sugar and yellow pines and are so destructive to pole and sapling stands."

Hopping (9) reported that Ips confusus was still epidemic in 1914 and in his published account of the outbreak attributed the cause to snowbreak.

"During the winter of 1912-13 the southern part of the Sierra Nevada Mountains extending from the Merced River on the north to King's River on the south was visited by a storm which caused a large amount of snowbreak, especially in pole and sapling stands. The slash bred a bark-borer, Ips confusus, which is very destructive to young growth of western yellow pine and the tops of mature trees of the same species. The beetles increased in this slash to such an extent that in the spring and summer of 1914 groups of 75 to 100 dying trees were not uncommon. Strenuous efforts have been made to check this epidemic in some of the more important commercial stands at a cost of $5,000."

3. Placerville, 1914-1916

That something of an outbreak occurred in the low elevation ponderosa pine around Placerville in 1915 is evidenced by the note entries of Burke and

Herbert. These observers, however, confined their attention largely to biology and did not attempt to analyze the infestation quantitatively. Herbert (2) reports that the outbreak was first noted in the fall of 1914. A group of 200 second growth trees was attacked several miles southeast of Placerville. In March 1916 Herbert rechecked this group and found that 60 of the trees were entirely dead and the remainder dead only in the top. Herbert also reported two other groups attacked in the fall of 1914 near Placerville, one of 75 and the other of 32 trees. Most of the insects found were Ips confusus, but some Ips calligraphus was apparently mixed in with the infestation. The next year Herbert reported:

> "During 1915 there was very little infestation. Evidently climate or other conditions were unfavorable to these insects, causing them to diminish greatly."

In February 1916 Burke and Herbert again found groups of trees containing overwintering broods of Ips confusus. Aside from one group of 35 trees, the infestation seems to have been in small groups of 4 or 5 top-killed trees. Herbert estimated that within a radius of 5 miles of Placerville, 1,000 trees had been killed or partially killed in recent years.

The evidence available does not indicate that this Placerville outbreak of 1914-1916 was very severe nor extensive. No contributing factors are mentioned in the records, and there is no mention of follow-up infestation by D. brevicomis. It may have been only a local flare-up and not an epidemic.

4. West slope of Sierras, 1929-32

This outbreak was the most extensive and aggressive of any on record. It is known to have extended through the ponderosa pine type between the elevations of 3,000 and 5,000 feet from the Kaweah drainage in the south to the Tuolumne in the north. It was characterized by the large groups of top-killed trees, some of which contained as many as 200 large trees. The killing of pole stands was a minor phase of this outbreak. Distribution of infestation centers was irregular, some watersheds being much more heavily infested than others. Areas where the heaviest infestations have occurred have been noted as Mill Creek, on the King's River, Cascadel Basin and Bass Lake near Northfork, and Anderson Valley on the Stanislaus National Forest.

This outbreak seems to have developed first in the more southern watersheds in 1929, but did not become specially noticeable in the northern areas until 1930. Reporting on the Kings River District, Salman (10) stated:

> "In all the areas losses appear to have been heavy for at least two seasons (1929 and 1930), and epidemic conditions are evidenced by the 'grouping-up' of the insect-killed trees. Losses previous to 1929 are difficult to estimate, but from the evidence collected it is believed that an endemic infestation had existed in the areas for some time.
>
> "In the areas listed, there has been a substantial increase in the number of trees killed during the past season (1930). An unusual feature to be noted is the large number of top-killed trees. The western pine beetle and Ips confusus are evidently the only species of insects causing serious losses in the four areas considered."

The behavior of the outbreak in the Northfork and Bass Lake areas of the San Joaquin drainage is described by Furniss (3).

> "Ips confusus, the five-spined engraver beetle, replaces Ips oregoni in the Sierra foothill region as the factor causing top-killing of ponderosa pine. In the abnormally dry year of 1924 Person noted at Cascadel that 69 out of 152, or 45 percent, of the trees marked were top-kills caused by Ips confusus. The drought-weakened condition of the trees was considered as increasing the number of secondaries at that time.
>
> "In 1931 a much more serious infestation of Ips confusus took place. Just what course this infestation followed is not known. In 1929 a normal infestation of D. brevicomis was running its course at Cascadel. In 1930 the area was not visited. By July of 1931 top-killing was fairly heavy throughout the Cascadel Basin. By the fall of 1931 the height of the infestation had been reached. An early spring cruise in 1932 of the 1931 losses showed 494 top-kills out of 843 infested trees on a half section. Person's 69 top-kills in 1924 covered about four sections, so the relative amounts on infestation are apparent.
>
> "The Cascadel infestation may be taken as indicative of the amount of damage done in 1931 by Ips confusus. The infestation by this insect took the shape of a band 3,000 to 4,000 feet in elevation and extending from General Grant Park to Yosemite Park."

Salman (11) found conditions on the Stanislaus National Forest in 1931 very similar to those at Bass Lake and Cascadel. On a half section check plot in Anderson Valley he found that 2.03 percent of the stand had been killed in 1930 and 4.04 percent in 1931. He reported that:

> "The losses were caused primarily by the western pine beetle, but numerous top-killed trees were in evidence, and the California five-spined engraver beetle (Ips confusus) was found to be an important element in the infestation of this Basin."

The sudden decline of the Ips confusus infestation in 1932 as described by Furniss (3) applies to the entire area involved in this outbreak. Everywhere Ips subsided and no further important infestations have been reported from these areas up to 1944. The only explanation for the cause of this sudden reduction is offered in the report by Furniss that the attacks on the overwintering top-killed trees in the fall of 1931 failed to develop successful broods and not enough beetles emerged in the spring of 1932 to maintain the momentum of the infestation.

The underlying causes for this extensive outbreak of I. confusus on the western slopes of the Sierra from 1929 to 1931 have been left largely to speculation. Some effort was made to attribute the heavy infestations in the Cascadel Basin and nearby areas to the closing down of the Sugar Pine Lumber Company's operation in the mid-summer of 1930, leaving a great amount of green slash within a few miles of where the main centers of concentration occurred. But the fact that equally large infestation centers developed elsewhere many miles from any known slash concentrations seems to make this theory untenable.

Salman (10) investigated the growth rate of living and infested trees in the Kings River District and offered an explanation which because of similar growth measurements elsewhere can be applied to all of the areas involved in this outbreak.

> "A study of the cores revealed that except for a marked decrease of growth in insect-attacked trees in 1930, in most cases a result of attack before growth has been completed, there was no consistent difference to be found between the growth rates of living and insect-attacked trees. However, a general depression of growth during the past few years was exhibited by the cores of both living and insect-killed trees. It may be possible that this slowing down of the growth rate of the entire stand has resulted in a marked increase in the susceptibility of all of the trees."

5. Northern California, 1938.

Salman (12) reported unexpected killing of groups of poles and immature trees extending through a number of areas in northern California representing the Coast Range and west slopes of the Cascades and northern Sierras. From Hopkins notes taken at the time, the only engraver beetle identified with these outbreaks was Ips confusus. However, Ips oregoni may have been involved in several east-side areas. Important westside localities noted were Clipper Gap, Stirling City, Magalia, Montgomery Creek, Cobb Mountain Area and Los Pasados State Park. In the two latter localities, the group killing affected a number of resort areas and a considerable amount of control work was carried on. Salman suggested that the infestation developed out of fairly heavy windfall damage which occurred during the winter of 1937-38.

6. Outbreaks in Southern California Areas from 1915 to 1940

In this sub-region the records of outbreaks appear only in Hopkins notes and interrupted series of survey reports so that few if any of the reported outbreaks can be followed from beginning to end.

a. Julian area, 1915. In September 1915 Keen (Hopk. 13282c) found I. confusus in Coulter pine near Julian and reported a condition that was obviously epidemic.

> "Bark beetles are doing a tremendous amount of damage on one hillside, about one-half of the trees have been killed with new infestation abundant."

b. Dyche Valley, Cleveland National Forest, 1930. Salman (13) found a heavy infestation in Coulter pine in the fall of 1930, which had been underway for several years. On one section 65 percent of the stand had been killed. Although D. brevicomis was considered to be the insect responsible for most of the loss, there was unmistakable evidence of extensive preliminary top-killing by Ips. The cause of this epidemic was attributed to the after effects of a nearby burn in 1928 where many scorched trees had served as a breeding ground for bark beetles.

c. Lake Arrowhead District, San Bernardino National Forest, 1939. The highly developed summer home areas of the Crestline and Lake Arrowhead units were subjected to a severe epidemic of Ips confusus during the summer and fall of 1939. Practically all of the infestation occurred in ponderosa pine. In the survey report for that year, Carlson (14) reported:

> "The infestation in the east half of the Crestline unit from Seely Creek to Lake Gregory is epidemic. Groups of immature ponderosa pines have been top-killed by the pine engraver beetle and the remaining bole attacked by the western pine beetle. The infestation has received much comment and caused much concern because of losses on developed home sites and the large groups just south of Lake Gregory. One group of 43 pines was tallied in this vicinity. It is believed that road construction and development operations (clearing of reservoir site) which resulted in accumulated slash have induced insect attacks here.
>
> "The infestation in the Arrowhead unit has shown an increase for two seasons and has reached epidemic proportions in the majority of the forest stand. Losses in groups are characteristic, although large single trees have succumbed to attack."

Very thorough control work was carried on against this infestation during the winter of 1939-40, mainly to control the western pine beetle, but Ips groups were treated wherever they were found to be infested. In the survey report for 1940, Miller (15) reported:

> "The western pine beetle which was epidemic in the Crestline-Lake Arrowhead units in 1939 was brought under control and its activity in these areas is now lower than it has been for a number of years. The aggressive top-killing of mature trees and group killing of poles by the engraver beetle, Ips confusus, has largely subsided during the 1940 season."

d. Julian Area, 1940. Heavy infestations were found in this area about 1933-35 by Ashley Brown, CCC insect control foreman, but no formal reports were made. Control work was carried on by the County Relief Camps and the infestation seems to have subsided until 1940 when Miller (16) reported another outbreak in this area.

> "In the Julian unit the Ips-western pine beetle in Coulter pine reported last year has been increasing and spreading into new territory. This infestation apparently originated around the eastern border of the 1935 burn where it was localized in the fall of 1939. In the fall of 1940 large groups were found in the area west of Julian which had been relatively free of infestation previously. New groups were also found to be springing up in the Pine Hills unit to the south, which also seems to be part of the spread from the original center around the burn."

7. Summary of the behavior and probable causes of outbreaks.

In this review of Ips confusus outbreaks which have been observed in the past, the following salient points seem to stand out which apply to their behavior and their probable causes.

1. When epidemic conditions first develop they have first appeared in standing trees during the late summer and fall.

2. These outbreaks have usually reached their peak at the close of the season when they first appear, or during the season following.

3. The momentum of these outbreaks has not lasted longer than two or at most three seasons.

4. Nearly all outbreaks have declined very suddenly after reaching the peak.

5. Conditions which have been suggested as factors contributing to outbreaks of Ips confusus include:

(a) Windfalls . . . . . Keen, Lambs Mine unit, 1915
. . . . . Salman, Nor. California, 1938
(b) Snowbreak . . . . . Hopping, Sierra, 1914
(c) Slash from wood cutting . . . . . Keen, Lambs Mine unit, 1915
(d) Flooding of pole stands by reservoir. . Dudley, Bass Lake, 1912
(e) Logging slash . . . . . Hopping, Sierra N. F., 1913
. . . . . Miller, Cascadel Area, 1931
(f) Slash from road and reservoir development....Carlson, Crestline unit, 1939
(g) Drought . . . . . Person, Cascadel Area, 1924
(h) Suppression of tree growth. . . . . Salman, Kings Canyon Dist. 1931
(i) After effects of fires. . . . . Salman, Dyche Valley Area, 1930
. . . . . Miller, Julian Area, 1940

For the majority of the cases on record, however, no satisfactory or convincing explantations of the causes for Ips outbreaks have been found. The breeding up of Ips populations in some form of slash material prior to their attack on standing trees has been most frequently assigned as the influencing factor; but enough exceptions have been found where no slash was present to make it fairly certain that less specific factors such as climatic conditions are also involved, and that these must be just right to insure widespread and virulent outbreaks.

VI. CONTROL OF IPS CONFUSUS

1. Methods

No special methods have been successfully developed for the direct control of Ips confusus other than the cut-peel-burn or cut-burn technique. Usually the infestation in the thin bark of tops and limbs can be successfully burned without peeling when the infested lengths are cut into short logs and are well piled before firing. Because of the habit of I. confusus to overwinter mainly in the new adult stage, peeling is not desirable unless care is taken to guard against escape of the new beetles after the bark has been removed.

One experiment was carried out by Yuill (17) in 1938 to test the effect of oil treatment on sugar pine and ponderosa pine tops infested by Ips confusus. Yuill used Formula B (light stove oil, 3 parts; Diesel oil, 1 part; and naphthalene, 3/4 lb. per gallon) and Standard Oil formula 21046R. Control ranged from "54.4 percent to 80.9 percent and was generally irregular because of irregular penetration through the bark. The method seems to offer very little promise for practical use for infested ponderosa pines or sugar pines." Indirect control methods will be discussed under "Policy."

2. Policy

a. Direct control.

In the long history of bark beetle control up to 1944, no projects have been undertaken in commercial pine stands to control Ips confusus specifically. Wherever this beetle has been involved in a control operation, it has been associated with D. brevicomis or D. monticolae, or both; and the project plans were drawn and methods were selected to control primarily the Dendroctonus species. The general strategy seems to have been based on the expectation that the Ips would soon subside anyway, and that the only serious continuing losses would be caused by Dendroctonus infestations building up in the wake of Ips top-killing.

On summer home tracts, parks and recreational areas, however, the control of Ips has been considered an essential phase of the control program and measures have been undertaken to eradicate them. In these areas where tree cover takes on high values because of esthetic reasons, it is usually considered that even a small amount of pole killing and injury to larger trees by top-killing was undesirable, and that the best course was to reduce Ips infestations to a minimum. In the Lake Arrowhead and Lake Tahoe tracts even the top-killed trees have been climbed and infested tops cut out and destroyed.

In the first projects undertaken in commercial pine areas, the treatment of Ips infested trees seems to have been accepted on general principles. Ips infested poles were treated along with Dendroctonus trees. On the Contour and other early projects conducted by the Forest Service, Hopping's instructions were insistent upon the treatment of Ips infestation as an essential requirement of bark beetle control.

Beginning about 1920 the projects under the technical supervision of the Bureau of Entomology and Plant Quarantine began to deemphasize the control of Ips beetles. Instructions for the Southern Oregon-Northern California project in 1922 provided that trees infested only with Ips were not to be treated. On the Sugar Pine sale and Fence Meadow projects of the Sierra National Forest in 1931-1932 a distinction was made between Ips infested top-killed trees which were left untreated, and top-killed trees infested by Ips in the top and D. brevicomis in the lower bole which are treated in their entirety. The amount of crown which had faded was used as a guide to distinguish between top-killed trees to be treated and those that were not to be treated. Trees with less than 50 percent of the crown fading were not treated unless there were evident signs of D. brevicomis infestation; while those with more than 50 percent faded were marked for control whether or not they contained D. brevicomis infestation.

The general policy regarding Ips on all direct control projects since 1920 has been to treat this infestation only when it could be included with the control of D. brevicomis and D. monticolae, except on parks, recreational areas, and other conditions where the character of the damage caused by Ips was considered to be a serious threat to tree cover values.

b. Indirect control.

Agencies concerned with timber management have given considerable attention to the prevention of Ips outbreaks. This has taken the trend of eliminating conditions under which Ips populations are known to multiply. Insistence upon prompt cleaning up of slash from intermittent cuttings was the chief measure advocated, and for a number of years the Forest Service in Region 5 required that the slash on all right-of-way cuttings or other developments on National Forest lands should be disposed of according to entomological requirements. Later it was found through studies by Person (18) and Beal (19) that scattering the slash so that it would get plenty of exposure to the sun was fairly effective in preventing the breeding of Ips and other bark beetles. This policy, however, was never carried to the point of requiring special slash disposal measures on timber sale operations, and the requirement of slash disposal for entomological reasons on other operations has not been followed closely in recent years.

In 1927 the Bureau of Entomology and Plant Quarantine came out with a circular (20) giving its recommendations for the disposal of slash to prevent bark beetle epidemics. For ponderosa pine, which largely includes the Ips confusus problem, the following statement was made:

> "In general it may be said that in the light of present information, no special methods of slash disposal need be recommended to avoid insect damage to western yellow pine except in the case of sporadic cutting or when logging operations cease. In such cases, infested slash material should be destroyed before the broods of insects emerge."

So far this policy has not been modified by any published statements.

Studies have been made in eastern Oregon by Buckhorn (21) to determine the relation of time of cutting to severity of damage by Ips oregoni to pole stands in and around slash areas. Buckhorn found that only 3.9 percent of the total loss to young stands was caused on areas where the slash was created during the period from August to January, inclusive; for February cutting the percent of loss was 10.9 percent; March, 18.4 percent; April, 201 percent; May, 23 percent; June, 18.9 percent; and July, 3.9 percent. Buckhorn's conclusions were:

> "From these data it would appear that from August to January would be a safe time to carry out cutting or thinning operations on hazardous areas when there may be danger of epidemics developing. Additional data, however, will be needed to determine if this behavior of Ips remains constant year after year."

Whether or not this relation of outbreaks in young stands to the time when the cuttings are made can be applied to Ips confusus is a question which cannot be answered from the present information on this species.

In the Southwest Regions a special method was developed for preventing the breeding of Ips in pole size trees cut on rights of way and other developments in young pine stands without burning. This method termed "partial bark peeling" is described by Hornibrook (22) as follows:

"In general they (5 species of Ips found in the Southwest) are found in endemic numbers and act as scavengers breeding in logging slash, cull logs, mechanically injured, lightning-struck and windfallen trees. They seldom become abundant enough to seriously threaten vigorous living stands except in the case of improvement cutting or logging operations that are suddenly curtailed, leaving insufficient slash for the increased population to enter.

"The CCC and NIRA timber stand improvement operations throughout the Southwestern Region have necessitated the cutting of many trees. In order to guard against building up an Ips population of epidemic proportions, the Regional instructions call for partial peeling of all poles 4 inches and over in diameter cut during the summer months, leaving strips of bark not exceeding 3 inches in width. It was anticipated that new adults would attack the poles, make their galleries in the strips and lay eggs as in the normal development of a new generation; and that the subsequent drying out of these narrow bark strips would result in high mortality of the larvae and pupae."

Hornibrook's paper described the results secured from this treatment which were quite successful where the width of the strips of bark left on the logs were not over 2 or 3 inches.

VII. APPRAISAL OF PRESENT INFORMATION ON IPS CONFUSUS

The accumulated information on Ips confusus gives a fairly complete picture of the distribution of this beetle and the hosts in which it occurs in the California region. However, there are many gaps yet to be filled before we have a satisfactory understanding of its habits, of the factors causing its sporadic outbreaks and the basis for a sound control policy. The present information seems to be inadequate in the following phases:

1. Seasonal history and habits.

Only the high spots have been touched upon so far. The number of seasonal generations have not yet been worked out because no studies have yet followed development throughout an entire season. Habits of the adults need to be studied to determine the length of time that they may live, possible hibernating habits and their flight range.

2. Ecology.

The causes to which epidemics have so far been attributed are largely speculative. Even the influence of slash as the cause of outbreaks has not been definitely proven. There is need for exploration of the climatic and biological influences that may be involved in the behavior of Ips confusus infestations.

3. Control.

Control of this beetle has so far been incidental to the control of Dendroctonus species. New direct control methods through the use of oils, DDT and repellents, if they can be developed, would aid greatly in the protection of individual trees

of high value. No indirect control or preventive measures have yet been proven for Ips confusus. The most promising field seems to lie in a study of the seasonal timing of cutting to see if logging and other operations can be regulated so as to prevent outbreaks in green trees.

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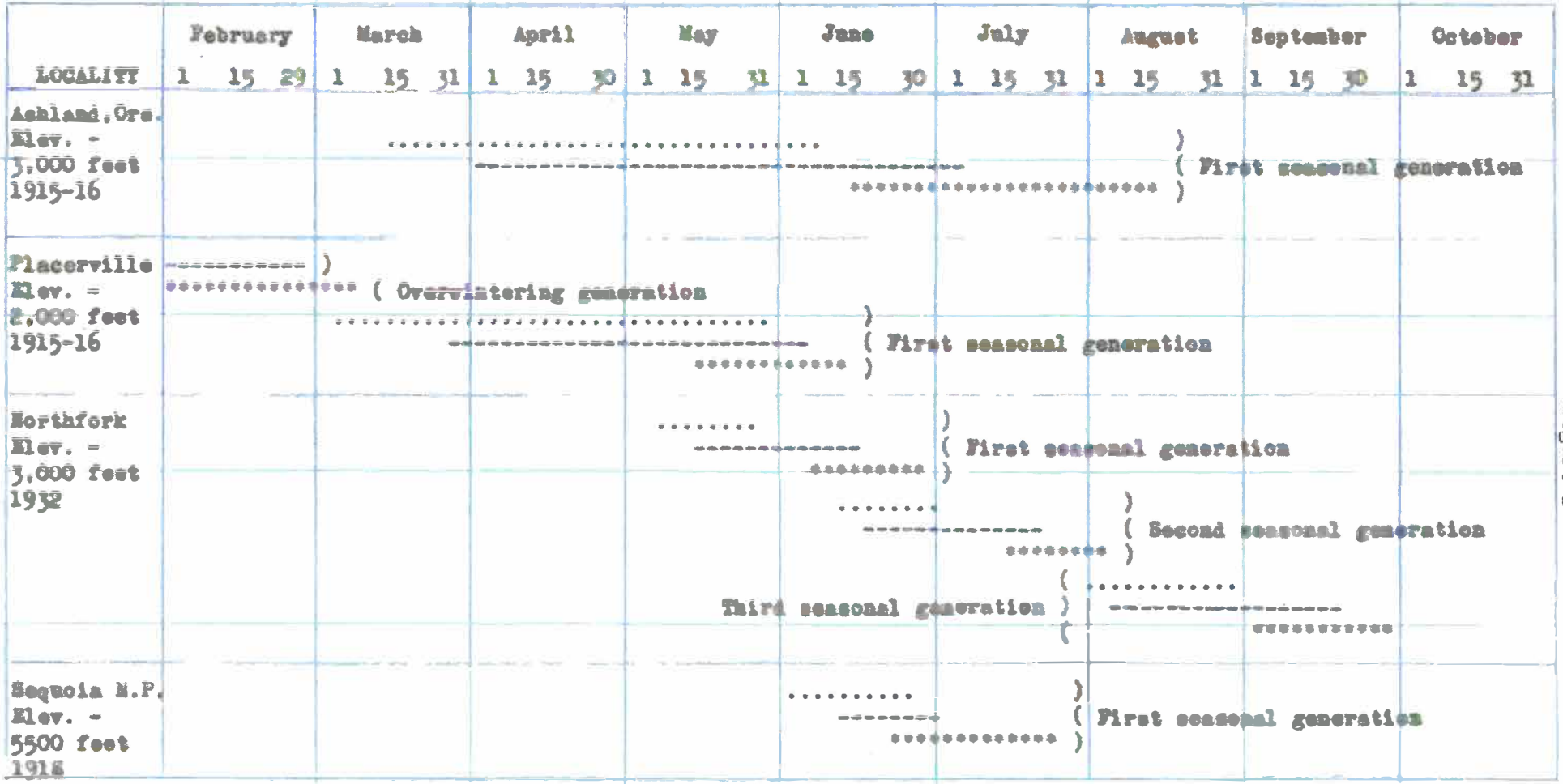
DIAGRAM OF BROOD DEVELOPMENT OF IPS CONFUSUS AS RECORDED IN DIFFERENT LOCALITIES



LEGEND

Attack and eggs .....
Larvae and pupae ----------
New adults, emergence **********

Figure 1

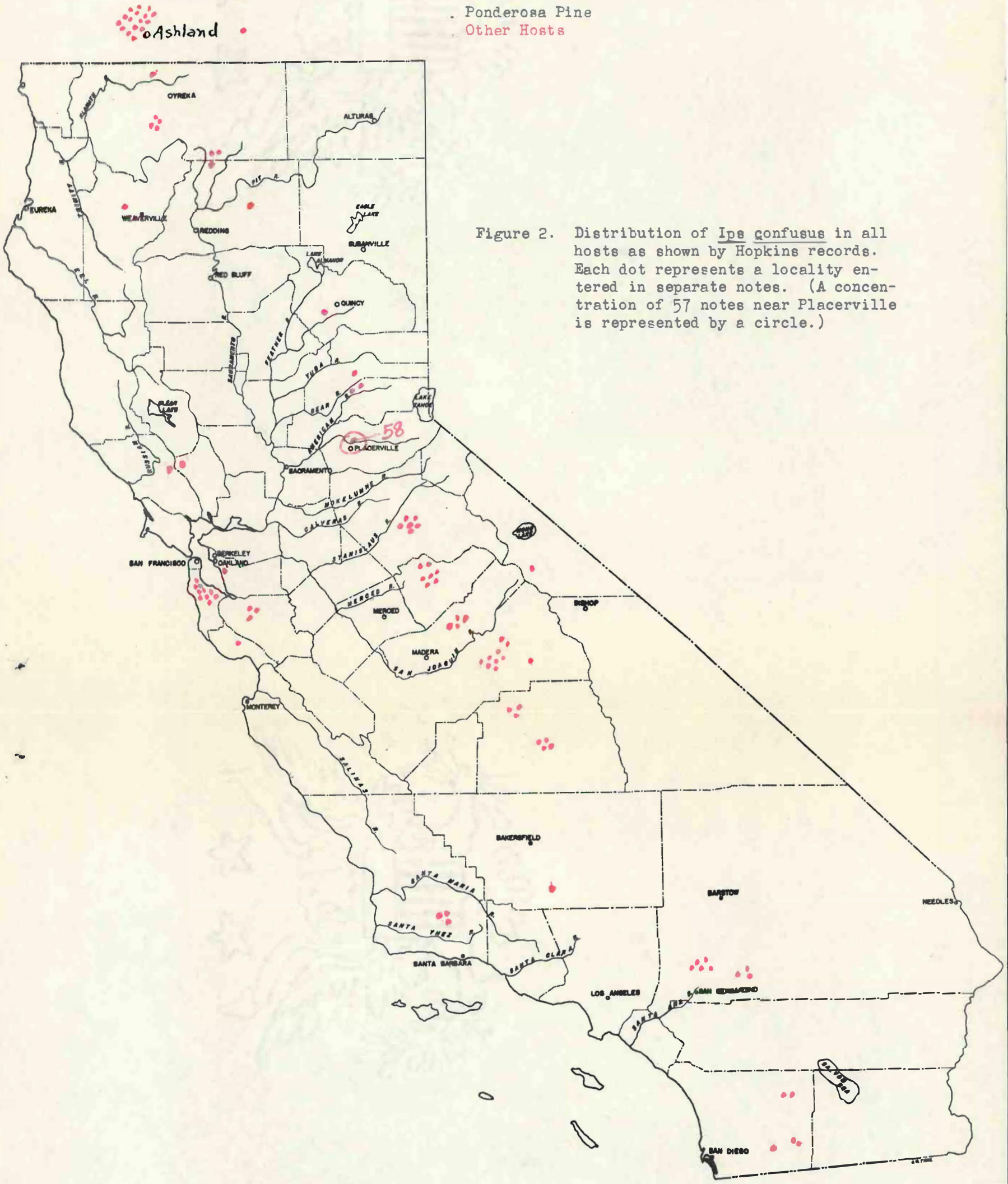


Figure 2. Distribution of Ips confusus in all hosts as shown by Hopkins records. Each dot represents a locality entered in separate notes. (A concentration of 57 notes near Placerville is represented by a circle.)

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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

WASHINGTON, D. C.

Forest Insect Laboratory
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Berkeley 4, California

January 19, 1945

To: P. P. Keen, in Charge, Berkeley Laboratory

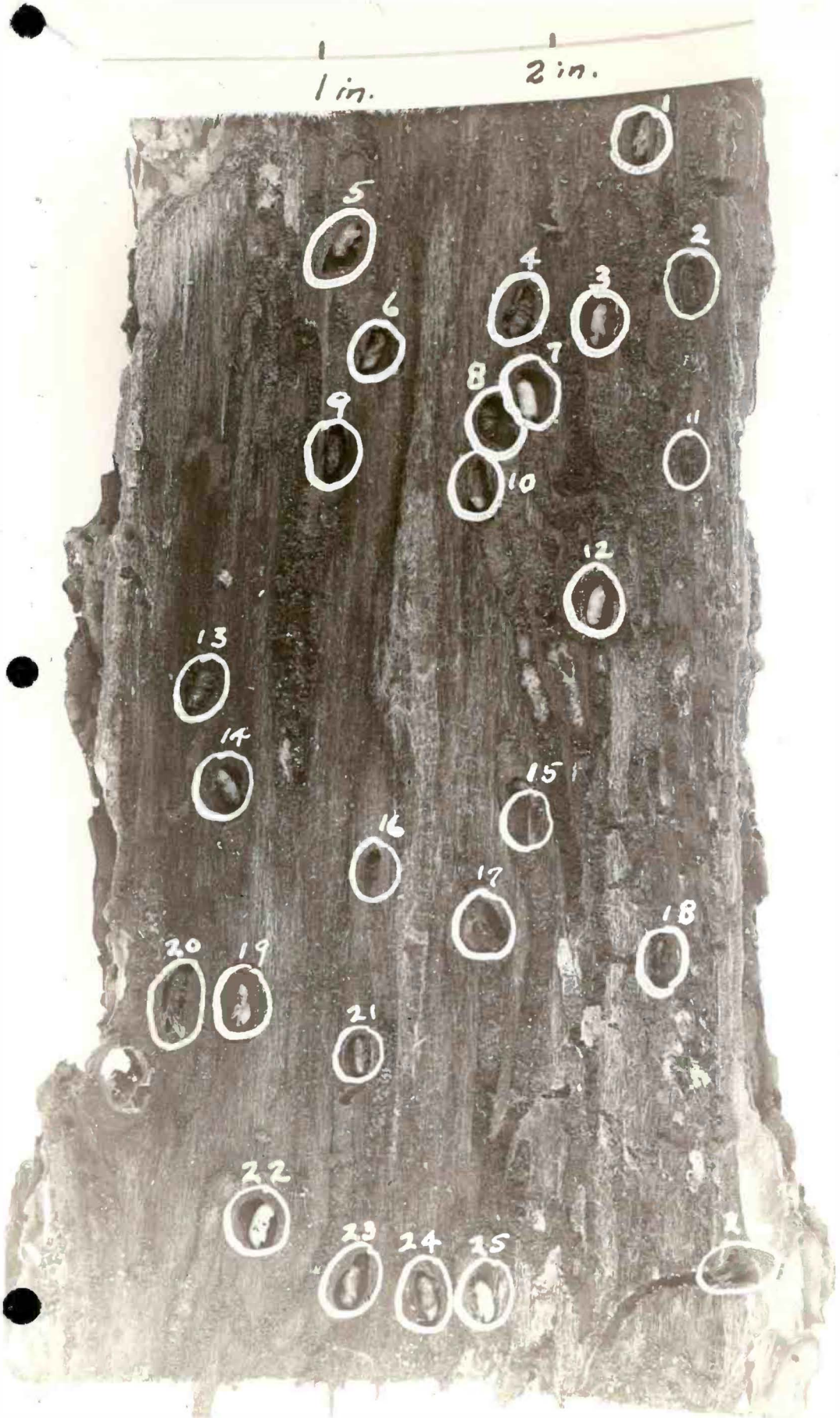
From: R. C. Hall, Entomologist

Subject: Overwintering Brood Stages of Ips confusus in the Burney Area

In Dr. Craighead's letter of January 3 he raised the question of the overwintering brood stages of Ips confusus in the Burney Area where control recommendations had been made for control this coming winter. The attached picture shows the general condition of the brood found in practically all small trees that have been sampled on the areas cut over in the spring and early summer of 1944.

This particular sample was taken about three feet above the ground from a ponderosa pine pole 4 inches d.b.h. in an area containing an average of ? ten trees to the acre. Population density based on this sample would be about 250 beetles per square foot of bark surface. It is estimated that 150 this particular 4 inch pole would have produced about 3,000 adult beetles.

RCHall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